Water Hyacinth (*Eichornia crassipes*)

ITS VALUE AS A FERTILIZER

BY

R. S. FINLOW, B.Sc., F.I.C.,
Government Fibre Expert, Bengal,

AND

K. McLEAN, B.Sc.,
Deputy Director of Agriculture, Eastern Bengal.

CALCUTTA
SUPERINTENDENT GOVERNMENT PRINTING, INDIA
1917

Agents for the Sale of Books published by the Superintendent of Government Printing, India, Calcutta.

IN EUROPE.

Constable & Co., 10, Orange Street, Leicester Square, London, W.C.

Kegan Paul, Trench, Trübner & Co., 68-74, Carter Lane, E.C., and 25, Museum Street, London, W.C.

Bernard Quaritch, 11, Grafton Street, New Bond Street, London, W.

P. S. King & Sons, 2 & 4, Great Smith Street, Westminster, London, S.W.

H. S. King & Co., 65, Cornhill, E.C., and 9, Pall Mall, London, W.

Grindlay & Co., 54, Parliament Street, London, S.W.

Luzac & Co., 46, Great Russell Street, London, W.C.

W. Thacker & Co., 2, Creed Lane, London, E.C.

T. Fisher, Unwin, Ltd., 1, Adelphi Terrace, London, W.C.

Wm. Wesley & Son, 28, Essex Street, Strand, London.

B. H. Blackwell, 50 & 51, Broad Street, Oxford.

Deighton Bell & Co., Ltd., Cambridge.

Oliver and Boyd, Tweeddale Court, Edinburgh.

E. Ponsonby, Ltd., 116, Grafton Street, Dublin.

Ernest Leroux, 28, Rue Bonaparte, Paris.

Martinus Nijhoff, The Hague, Holland.

IN INDIA AND CEYLON.

Thacker, Spink & Co., Calcutta and Simla.

W. Newman & Co., Calcutta.

R. Cambray & Co., Calcutta.

S. K. Lahiri & Co., Calcutta.

B. Banerjee & Co., Calcutta.

The Indian School Supply Depôt, 309, Bow Bazar Street, Calcutta, and 226, Nawabpur, Dacca.

Butterworth & Co. (India), Ltd., Calcutta.

Rai M. C. Sarcar Bahadur and Sons, 90-2-A, Harrison Road, Calcutta.

The Weldon Library, 18-5, Chowringhee Road, Calcutta.

Standard Literature Company, Ltd., Calcutta.

Lal Chand & Sons, Calcutta.

Higginbothams, Ltd., Madras.

V. Kalyanarama Iyer & Co., Madras.

G. A. Natesan & Co., Madras.

S. Murthy & Co., Madras.

Thompson & Co., Madras.

Temple & Co., Madras.

P. R. Rama Iyer & Co., Madras.

Vas & Co., Madras.

E. M. Gopalakrishna Kone, Madura.

Thacker & Co., Ltd., Bombay.

A. J. Combridge & Co., Bombay.

D. B. Taraporevala, Sons & Co., Bombay.

Mrs. Radhabai Atmaram Sagoon, Bombay.

Sunder Pandurang, Bombay.

Gopal Narayan & Co., Bombay.

Ramchandra Govind & Son, Kalbadevi, Bombay.

A. H. Wheeler & Co., Allahabad, Calcutta and Bombay.

N. B. Mathur, Supt., Nazir Kanun-i-Hind Press, Allahabad.

Rai Sahib M. Gulab Singh & Sons, Mufid-i-Am Press, Lahore.

Rama Krishna & Sons, Lahore.

Supt., American Baptist Mission Press, Rangoon.

Manager, the "Hitavada," Nagpur.

S. C. Talukdar, Proprietor, Students & Co., Cooch Behar.

A. M. & J. Ferguson, Colombo, Ceylon.

Manager, Educational Book Depôts, Nagpur and Jubbulpore.*

Manager of the Imperial Book Depôt, 63, Chandney Chauk Street, Delhi.*

Manager, "The Agra Medical Hall and Co-operative Association, Ltd." (Successors to A. John & Co., Agra.)*

Supt., Basel Mission Book and Tract Depository Mangalore.*

P. Varadachary & Co., Madras.*

H. Liddell, Printer, etc., 7, South Road, Allahabad.*

Ram Dayal Agarwala, 184, Katra, Allahabad.*

D. C. Anand & Sons, Peshawar.*

Manager, Newal Kishore Press, Lucknow.*

* Agents for the sale of Legislative Department publications only.

INTRODUCTION.

THE water hyacinth has, within recent years, become a very serious pest in parts of India, particularly Burma and Bengal. In the former Province the pest has become so widespread that it has been found necessary to legislate against it, and the Burma Water Hyacinth Bill has been passed in the local Legislative Council.

The object of the present Bulletin is to indicate that a certain return can be obtained from the plant in the process of exterminating it. It is to be hoped that the possibility of utilization of this pernicious weed will not lead to a *laissez-faire* policy with regard to its spread. Its extermination and not its commercial exploitation is to be aimed at; but efforts to get rid of it will probably be more energetic if some return is obtained for the labour involved.

J. MACKENNA,

Agricultural Adviser to the Government of India.

PUSA,

March 16, 1917.

Water Hyacinth *(Eichornia crassipes)*

Its value as a fertilizer.

[*Received for publication on the 31st January, 1917.*]

IN recent years the growth of water weeds has increased to an alarming extent in the *bheels* [1] and *khals* [2] of the Dacca District of Bengal. There are two aquatic plants which are extremely common in this tract, viz.,—

(*a*) *Pistia Stratiotes* (vernacular—Pana Gach) which has been known from time immemorial and which even now is showing no marked tendency to increase.

(*b*) Water Hyacinth; *Eichornia crassipes*, Solms.; vernacular—Kachuri, Tagoi, Belati pana in Bengal; Bedaxbin in Burma.

The latter plant has been known in the neighbourhood of Calcutta for a number of years; but it is said to have been introduced to Narayanganj, for ornamental purposes, only about five years ago. It is similar to *pana gach* in that both plants normally float on the surface of the water and possess abundant sub-aqueous roots; but instead of the small size and flat-above-water appearance of *pana gach*, the hyacinth leaves stand out of the water to heights varying from six inches to over three feet.

We are indebted to Mr. H. G. Carter, Economic Botanist to the Botanical Survey of India, for the following technical description of water hyacinth:—

"*Eichornia crassipes*, Solms., belonging to the Family *PONTEDERACEÆ*, is a native of South America but has now become a troublesome weed in other countries, notably Florida, Java, Australia and India. The plant is a herb which multiplies extensively by division of the root-stock.

"When floating in water the plant has large bladder-like leaf-stalks which make it remarkably buoyant. The blade of the leaf acts as a sail, so that the plant, which multiplies very

[1] The basin-like depressions which are known as *bheels* in North-Eastern India, *chars* or *tals* in Bihar, always hold water in the rains. Some are small and shallow and such as these probably dry up in the hot weather. On the other hand some *bheels* are very large, covering perhaps hundreds of square miles in the monsoon season and forming, even in the dry weather, permanent lakes of considerable size.

[2] In Deltaic Bengal numerous river channels are often connected by water courses, artificial or otherwise. These water courses, which are called *khals*, are practically the only means of communication over large tracts of country, especially during the monsoon.

rapidly, is carried about on the surface of the water and soon becomes a pest. When growing in mud the bladder like expansion of the leaf-stalk is absent. The plants bear spikes of ten or twelve handsome lilac flowers. The perianth is funnel-shaped and usually slightly irregular; it ends in six lobes. The six stamens are inserted on the perianth. The ovary is superior and three-celled and has axile placentation. The fruit is a loculicidal capsule containing seeds with abundant mealy endosperm."

The apparent resemblance of the flower of *Eichornia crassipes* to that of the Hyacinth (*Hyacinthus orientalis*, Liliaceæ) is responsible for its English title; but it will be seen from the above description that no botanical relation exists between these two plants.

The water hyacinth is solely responsible for the justifiable alarm which its rapid invasion of the water courses of the Dacca District is creating. Starting apparently from Narayanganj it may now be found in many distant low-lying parts of the Dacca District and it has already established itself in places as far away as Nattore and Gaibanda, which are across the Brahmaputra, in the Rajshahi and Rangpur Districts, respectively. In some *khals* near Narayanganj it has formed such a dense mass of vegetation as to render navigation impossible unless the hyacinth is removed, and it is therefore not to be wondered at that the Narayanganj Chamber of Commerce considered the matter sufficiently important to bring before the Governor of Bengal, Lord Carmichael, about two years ago (1914).

In the investigation, which was subsequently commenced, at the instance of His Excellency, it was discovered that *Eichornia* sp. is a serious pest, interfering with navigation in Burma, Indo-China, Australia and in Florida. In Madras it has been the subject of a note written by the Director of Agriculture; in Burma it has been described as one of the greatest administrative problems at present confronting Government and special legislation has been carried through with the object of eradicating it. In Indo-China elaborate investigations have been carried out with the object of finding an economic use for the very large quantities of organic matter which are to be disposed of; but, as in the case of "Sudd," a water weed which has caused such difficulties in the navigation of the upper reaches of the Nile, the investigations have apparently tended chiefly towards commercial exploitation of the weed, such as the manufacture of paper and the extraction of salts of ammonium. In Cambodia Professor Perrot proposes to use the fibrous matter of the plant for the manufacture of bags to replace jute gunnies now imported from India.

So far as our information goes, no commercially successful enterprise has, as yet, been based on water hyacinth : but apart from this, such schemes as the above seemed too elaborate in regard to the present state of affairs in India. Moreover, much valuable time would have been lost, firstly, over the necessary experiments and, in the event of their success, in proving to the commercial world the economic possibilities involved in the results. It was decided therefore, in the meantime, to approach the matter from an agricultural point of view and, as a preliminary step, specimens were chemically examined in regard to their content of agriculturally valuable material.

The present note deals with the results of the analyses and also includes an account of field experiments based on the analyses and carried out at Dacca in the last season (1916).

The original analyses were made on samples of plant obtained in Narayanganj, and samples of *pana gach* were also included for purposes of comparison. The results have subsequently been confirmed by examination of numerous samples taken from widely different sources. It appears that the various parts of the plants (leaves, stem and roots) differ somewhat in their constitution ; for instance a larger percentage of potash has been found in the stems and leaves than in the roots. The following may be taken as the approximate content of important constituents in the whole fresh green plant :—

TABLE I.

	Per cent.
Moisture	95·50
Organic matter	3·50
(containing Nitrogen)	0·04
Ash	1·00
(containing Potash)	0·20
Phosphoric acid	0·06

A typical analysis of the completely dried plant is as follows :—

TABLE II.

	Per cent.
Organic matter	75·8
(containing Nitrogen)	1·5
Ash	24·2

The ash contained the following :—

	Per cent.
Potash (K_2O)	28·7
Soda (Na_2O)	1·8
Lime (CaO)	12·8
Chlorine	21·0
Phosphoric acid (P_2O_5)	7·0

The ash was therefore equivalent to chloride of potash of practically 50 per cent. purity, in addition to containing considerable quantities of lime and phosphoric acid.

In the following table the important manurial constituents of *pana gach*, water hyacinth and various samples of farmyard manure are compared on a common basis of 65 per cent. moisture content.

TABLE III.

Heads	Nitrogen	Phosphoric acid (P_2O_5)	Potash (K_2O)	Organic matter
	Per cent.	Per cent.	Per cent.	Per cent.
(A) Young Pana Gach (*Pistia Stratioites*)	0·85	0·32	0·96	..
(B) Mature Pana Gach (*Pistia Stratioites*)	0·60	0·20	2·17	24·15
(C) Water Hyacinth (*Eichornia crassipes*), normal size	0·45	0·32	2·52	27·95
(D) Water Hyacinth (*Eichornia crassipes*), large size	0·60	0·23	2·61	27·95
(E) Cowdung (Leather) . . .	0·61	0·60	..	17·16
(F) Cowdung (Voelcker) . . .	0·56	0·20	0·50	25·56
(G) Cowdung (Voelcker) . . .	0·45	0·23	0·25	26·00
(H) Cowdung of grazing cattle (Leather)	0·39	0·26	..	21·42
(I) Cowdung (Dumraon), (Leather) .	0·34	0·20	..	12·63

An examination of the above figures (Table III) shews that the characteristic feature of both the water hyacinth and *pana* is their high content of potash, which has been found to compose as much as 35 per cent. of the ash of some samples of the former. Rotted water hyacinth is approximately five times as rich in potash as farmyard manure containing a similar percentage of water. In one case as much as 0·3 per cent. of potash was found in fresh green plant, a specimen kindly procured, in the monsoon season, by Mr. Hely-Hutchinson of Narayanganj, from the centre of a large *bheel*.

It would seem therefore that the water hyacinth exercises a selective absorptive power for potash, as a source of which it is, on this account of considerable value.

Water hyacinth is apparently not as rich in potash as the best marine sources of Kelp. For instance, Hendrick (*The Journal of the Society of Chemical Industry*, volume XXXV, page 567) gives roughly 28 per cent. as the average total ash content of the dry matter of *Laminaria digitata* (stems and fronds). For *Fucus* the average total ash content in the dry matter is about 20 per cent., and the corresponding figure for dried hyacinth also approaches 20 per cent. On the other hand the percentage (K_2O) content of hyacinth ash (average about 25 per cent.) appears to be nearly equal to that of *Laminaria* (26 per cent.) and decidedly higher than *Fucus* (15 per cent.). Of course the Kelp also contains iodine, which is a valuable constituent, but the respective problems involved in the use of seaweed and of water hyacinth, either as organic manures or for the production of ash, are not dissimilar.

The high potash content of these weeds is of considerable importance in North-Eastern India where the soils of the old alluvium are, on account of the leaching effect of the heavy rainfall, generally deficient in lime, potash and phosphoric acid. This is especially the case in the two extensive laterite areas, *viz.*, the Madhupur jungle in Eastern Bengal (Dacca, Mymensingh and Tippera Districts), the Barind (Rajshahi, Bogra and Dinajpur) in Western Bengal and, probably also, in other large areas in Assam.

Returning to Table III the analytical figures indicate that, apart from its high potash content, water hyacinth is at least as rich as farmyard manure of the same water content in both nitrogen and phosphoric acid.

In the case of the rotted hyacinth used in the field experiments in 1916, the nitrogen content of the dry rotted material was as high as 2·24 per cent. and in the damp state (containing 67·8 per cent. of water) 0·72 per cent.

Field Experiments.

In order to put the analytical results to a practical test, a set of field experiments was designed with this object in view. In the previous year (1915) application of the carbonates of soda and potash had produced very marked increases in the yield of jute, and it was therefore decided to use jute as the test crop.

The hyacinth was applied both in the rotted state and, after burning, as ash. With the help of Mr. S. G. Hart, I.C.S., Collector of Dacca, and of the Dacca Municipality we were able to collect about 850 maunds (roughly 30 tons) of the fresh green plant from the *khals* in Dacca City and cart it to the Dacca Farm. Of this about 499 maunds was heaped and allowed to rot while the remainder (351 maunds) was spread out to dry and afterwards burnt. Owing to the very high water content the rotting

of the fresh green plant involved a considerable loss, in the form of liquid which was squeezed out in large quantities, during the decomposition process. That this loss was serious is shewn by the fact that while the rotted residue from practically 500 maunds of green plant was only sufficient to manure four plots (0·4 acre) at the rate of 78 lb. potash (K_2O) per acre, the ash from 351 maunds of green plant was sufficient to apply to 11 plots at the rate of 94 lb. per acre of potash (K_2O). In other words, by drying and burning the plant, the ash obtained from 300 maunds of green plant gave a larger quantity of potash than was obtained from 1,000 maunds of similar plant after rotting.

The actual details are as follows :—

	Mds.	Srs.
Rotted Hyacinth—		
Weight of fresh green hyacinth before rotting (*N.B.*—One maund = 40 srs. = 82 lb.)	498	31
Weight of residue after rotting	16	20
i.e., weight of rotted residue per 100 mds. of green plant	3	13
Approximate potash content of residue	2·5 per cent. K_2O	
Therefore total potash in rotted residue from 100 mds. (8,200 lb.) green plant	$\frac{266}{100} \times 2·5 = 6·65$ lb. K_2O	

	Mds.	Srs.
Hyacinth ash—		
Weight of fresh green hyacinth taken	356	39
Weight of ash after drying and burning	5	14½
Weight of ash per 100 mds. of green plant	1	20
Approximate potash content of ash	25 per cent. (K_2O)	
Therefore total potash in ash residue from 100 mds. green plant	30·5 lb. (K_2O)	

It would thus appear that the rotting process, as carried out, involved a loss of something like 70 per cent. of the available potash, and 60 per cent. of the nitrogen was also carried away. In the present season this loss is being avoided, for experimental purposes, by partly drying the plant before stacking and also, in another case, by mixing dried plant with fresh plant in the heap. Under ordinary circumstances of course earth, dry refuse or jungle would be equally useful.

Of the four plots manured with rotted hyacinth, two duplicates received lime at the rate of 20 maunds (1,640 lb.) per acre and the remaining two—also duplicates—were not limed. It was at first intended to apply the rotted material at the rate of 40 lb. of nitrogen per acre, so as to compare with the 40 lb. of nitrogen in the castor cake which the check plots received ; but through an error in calculation, only half this amount, *i.e.*, 20 lb. of nitrogen per acre was put on. This was

fortunate as it served eventually to accentuate the value of the potash, about 78 lb. per acre of which was contained in the rotted material actually applied. The potash in the castor cake was only about 8 lb. per acre.

The hyacinth ash was applied on the basis of its potash content at the rate of 94 lb. (K_2O) per acre.

As a check on the plots to which ash was applied, other plots were respectively given equivalent amounts of potash, in the form of sulphate of potash, with and without lime; carbonate of potash, with and without lime, and chloride of potash, with lime. In addition other plots received a mixture of sulphate and chloride of potash, with lime. To another set of plots carbonate of soda was applied, with and without lime, at the rate of 62 lb. per acre of Na_2O which is equivalent to 94 lb. per acre of K_2O; and to still another set a mixture of the carbonates of soda and potash with and without lime was applied at the rates of 22·5 lb. Na_2CO_3 and 110 lb. K_2CO_3 per acre, these being the approximate respective proportions of soda to potash in the hyacinth ash.

All the plots to which only salts were applied received castor cake in addition at the rate of 40 lb. nitrogen per acre.

The rotted *pana gach* was applied, with and without lime, at the rate of 40 lb. nitrogen per acre.

The land was typical of the Dacca Farm, and of the laterite tract in general, in that it is very uneven indeed and so it was necessary to include a very large number of checks. Out of a total 72 plots there were 22 checks and it was arranged that every plot should be adjacent to at least one check; in most cases as will be seen in the sequel, the mean of two or more checks has been taken. The results obtained are of course only approximations; but the margins over the checks are in nearly every case so large as to leave no doubt regarding the positive effect of hyacinth, both in the rotted state and in the form of ash. The fact that the rotted hyacinth plots received only half as much nitrogen as the checks, and yet gave higher yields, shews that the potash was the active constituent. This result is supported by the increased yields on the plots which received hyacinth ash, and on those to which salts of potash were applied; entirely similar results were also obtained in the previous year (1915) by application of potash to other plots.

The manurial history of the field is as follows:—

1912 . . . . . 30 mds. (2,460 lb.) slaked lime per acre.
1914 . . . . . 3 mds. (246 lb.) bonemeal per acre.

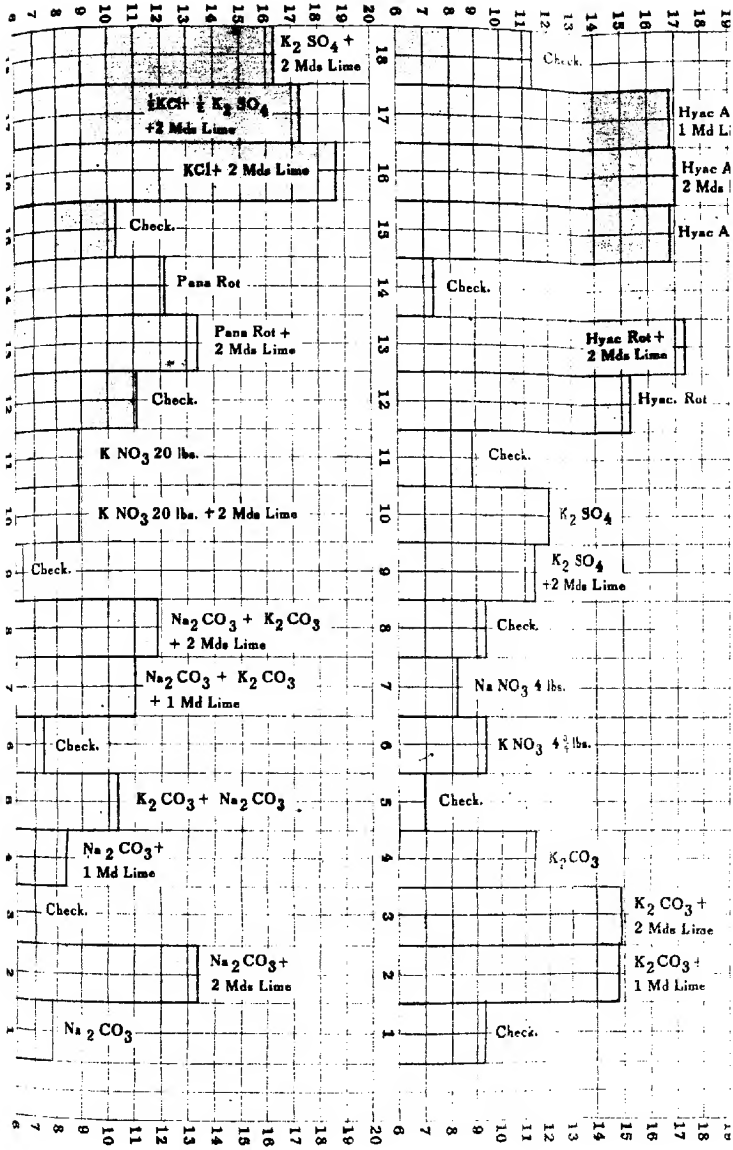
The season 1916 was unfavourable for jute in the laterite tracts.

After an early fall in February there was no more rain until the first week of April, after which there was constant wet weather for a fortnight. Sowing took place on the 23rd April after which, with the exception of showers early in May, there was no more rain until the second week in June. July brought another prolonged drought.

Results of the experiments.

Details of the yields of the various plots are given below (*N.B.*, 1 maund=40 seers=82 lb.). The yield of fibre per acre from each plot is also marked to scale on the attached plan of the field which, in addition, affords a bird's-eye-view of the arrangement of the plots :—

Number of plot	Yield per acre	Numbers of check plots	Yields of check plots	Mean of checks	Difference between experiment and mean of checks	Mean of duplicate differences per acre
	m. s.		m. s.	m. s.	m. s.	m. s.
	Rotted hyacinth without lime.					
5 b	13 33	4 b	9 36			
		7 b	6 27	8 22	5 11	
		5 a	10 27			
		5 c	6 36			5 8
12 c	15 0	11 c	8 36			
		14 c	7 11	9 34	5 6	
		12 b	12 10			
		12 d	11 2			
	Rotted hyacinth *plus* lime (20 mds. per acre).					
6 b	14 23	..	..	8 22	6 0	6 32
13 c	17 17	..	..	9 34	7 23	
	Rotted *pana gach* without lime.					
7 a	12 13	5 a	10 28	11 28	0 23	
		8 a	12 29			1 6
14 d	12 5	15 d	10 10	10 26	1 19	
		12 d	11 2			


K_2SO_4 + 2 Mds Lime
½KCl+ ½ K_2SO_4 +2 Mds Lime
KCl+ 2 Mds Lime
Check.
Pana Rot
Pana Rot + 2 Mds Lime
Check.
KNO_3 20 lbs.
KNO_3 20 lbs. + 2 Mds Lime
Check.
Na_2CO_3 + K_2CO_3 + 2 Mds Lime
Na_2CO_3 + K_2CO_3 + 1 Md Lime
Check.
K_2CO_3 + Na_2CO_3
Na_2CO_3 + 1 Md Lime
Check.
Na_2CO_3 + 2 Mds Lime
Na_2CO_3
Check.
Hyac A 1 Md Li
Hyac A 2 Mds
Hyac A
Check.
Hyac Rot + 2 Mds Lime
Hyac. Rot
Check.
K_2SO_4
K_2SO_4 +2 Mds Lime
Check.
$NaNO_3$ 4 lbs.
KNO_3 4 ½ lbs.
Check.
K_2CO_3
K_2CO_3 + 2 Mds Lime
K_2CO_3 + 1 Md Lime
Check.
BLOCK D
BLOCK C

Number of plot	Yield per acre	Numbers of check plots	Yields of check plots	Mean of checks	Difference between experiment and mean of checks	Mean of duplicate differences per acre
	m. s.		m. s.	m. s.	m. s.	m. s
	Rotted *pana gach plus* lime (20 mds. per acre).					
6 a	13 35	..	..	11 28	2 7	2 21
13 d	13 18	..	..	10 26	2 34	
	Hyacinth ash without lime.					
1 b	17 22	1 a	12 23	12 23	4 39	5 33
15 c	16 33	18 c	11 16	10 7	6 26	
		14 c	7 14			
		15 b	11 31			
	Hyacinth ash with lime (10 mds. per acre).					
2 b	13 38	1 c	9 9	9 22	4 16	5 21
		4 b	9 36			
17 c	16 33	..	..	10 7	6 26	
	Hyacinth ash with lime (20 mds. per acre).					
3 b	15 9	4 b	9 36	..	5 13	6 3
16 c	16 31	..	..	10 7	6 24	
	Carbonate of potash without lime.					
18 b	20 0	18 c	11 16	14 28	5 12	4 35
		18 a	18 0			
4 c	11 14	5 c	6 36	..	4 18	
	Carbonate of potash *plus* lime (10 mds. per acre).					
17 b	20 23	..	..	14 28	5 35	5 27
2 c	14 26	1 c	9 9	..	5 19	
	Carbonate of potash *plus* lime (20 mds. per acre).					
16 b	17 8	15 b	11 31	..	5 17	6 4
3 c	14 34	1 c	9 9	8 3	6 31	
		5 c	6 36			

Number of plot	Yield per acre	Numbers of check plots	Yields of check plots	Mean of checks	Difference between experiment and mean of checks	Mean of duplicate differences per acre
	m. s.		m. s.	m. s.	m. s.	m. s.
Mixed carbonates of soda and potash without lime.						
12 a	16 13	10 a	15 5	14 18	1 35	
		14 a	13 31			
5 d	10 14	3 d	7 0			2 26
		6 d	7 16	6 38	3 16	
		9 d	6 16			
Mixed carbonates of soda and potash *plus* lime (10 mds. per acre).						
13 a	16 20	..	..	14 18	2 2	3 2
7 d	11 0	..	..	6 38	4 2	
Mixed carbonates of soda and potash *plus* lime (20 mds. per acre).						
11 a	16 35	..	..	14 18	2 17	3 25
8 d	11 32	..	..	6 38	4 34	
Carbonate of soda without lime.						
15 a	15 6	14 a	13 31	..	1 15	1 0
1 d	7 26	3 d	7 0	..	0 26	
Carbonate of soda *plus* lime (10 mds. per acre).						
17 a	15 6	14 a	13 31	..	1 15	1 16
4 d	8 18	3 d	7 0	..	1 18	
Carbonate of soda *plus* lime (20 mds. per acre).						
16 a	15 32	14 a	13 31	..	2 1	3 15
2 d	11 30	3 d	7 0	..	4 30	
Sulphate of potash without lime.						
11 b	12 25	12 b	12 0			
		9 b	9 8	10 5	2 20	
		11 c	8 36			2 30
10 c	12 1	11 c	8 36			
		8 c	9 8	9 2	2 39	

Number of plot	Yield per acre	Numbers of check plots	Yields of check plots	Mean of checks	Difference between experiment and mean of checks	Mean of duplicate differences per acre
	m. s.	m. s.	m. s.	m. s.	m. s.	m. s.
Sulphate of potash *plus* lime (20 mds. per acre).						
2 a	14 24	1 a	12 22			
		5 a	10 28	11 2	3 22	
		4 b	9 36			
18 d	16 10	18 c	11 16	..	4 34	3 17
10 b	13 3	..	..	10 5	2 38	
9 c	11 15	..	..	9 2	2 13	
Mixed sulphate and chloride of potash *plus* lime (20 mds. per acre).						
3 a	13 34	..	..	11 2	2 32	
17 d	17 10	18 c	11 16			4 24
		15 d	10 10	10 33	6 17	
Chloride of potash *plus* lime (20 mds. per acre).						
4 a	15 31	..	..	11 2	4 29	
16 d	18 28	..	..	10 33	7 35	6 12
Nitrate of potash { 28 lb. nitrogen per acre / 77 lb. potash per acre } applied in three top-dressings.						
Castor cake . . . . . 12 lb. nitrogen per acre.						
Lime . . . . . 20 maunds per acre.						
9 a	16 35	8 a	12 19			
		10 a	15 5	13 32	3 3	2 32
10 d	8 36	9 d	6 16			
		12 d	..	..	2 20	
Nitrate of potash / Castor cake } as above (without lime).						
8 b	11 16	9 b	9 8	..	2 8	
11 d	8 35	12 d	11 2			1 7
		9 d	6 16	8 29	0 6	

Number of plot	Yield per acre	Numbers of check plots	Yields of check plots	Mean of checks	Difference between experiment and mean of checks	Mean of duplicate differences per acre
	m. s.		m. s.	m. s.	m. s.	m. s.
Nitrate of potash top-dressing of 48 lb. (KNO_3) per acre, 4·7 lb. nitrogen per acre.						
13 b	12 35	12 b	12 10	12 0	0 35	1 4
		15 b	11 31			
6 c	9 15	5 c	6 36	8 2	1 13	
		9 c	9 8			
Nitrate of soda top-dressing of 40 lb. ($Na\ No_3$) per acre, 4·0 lb. nitrogen per acre.						
14 b	11 8	..	..	12 0	−0 35	..
7 c	8 7	..	..	8 2	+0 5	

Discussion of the results.

It has already been pointed out that potash is the characteristic constituent of water hyacinth: it has also been mentioned that extraordinary results were obtained with potash on jute in the season 1915, when the addition of carbonate of potash to an otherwise complete manure of castor cake, phosphates and lime, produced the phenomenal yield, on duplicate plots, of nearly 34 mds. of fibre per acre. Duplicate check plots which did not receive potash, but which were otherwise similarly treated, produced less than 27 maunds per acre. There was therefore a margin of over 7 maunds per acre in favour of the potash. In view of this it was to be expected that any effect produced by the hyacinth, either in the rotted state or as ash, would be due to its potash and the results of the experiments entirely confirm this idea: further support is also afforded by the enhanced yields obtained from the plots which received potash in the respective forms of carbonate, chloride and sulphate, especially the two former. The effect of the chloride of potash, as contrasted with that of sulphate of potash, is interesting in view of the fact, already mentioned, that a high percentage of chlorine was found in the hyacinth and that the hyacinth ash contained nearly 50 per cent. of chloride of potash.

In other experiments with jute on laterite soils at Dacca it has been found that an application of 30 maunds of lime (approximately

1 ton) per acre results in an increased yield of 4 maunds of fibre per acre; moreover the effect of the lime lasts for at least three years.

The land on which this year's (1916) experiments were carried out received 30 maunds of lime per acre in 1912 and it is probably due to this that the effect of the lime applied in 1916, though favourable, is comparatively slight.

The *pana gach* used in the experiments was mixed with a large proportion of earth: it was collected from a place where, the floods having receded early, the *pana* had taken root where it was deposited.

The potash content in its ash was only 2·7 per cent. as against 26 per cent. for hyacinth.

It is perhaps advisable, before concluding this note, to again point out that about 95 per cent. of the weight of fresh green hyacinth consists of water; it would not therefore be an economic proposition to transport the green plant over any considerable distance.

The well-rotted residue would probably contain from 50 per cent. to 60 per cent. of water; in this state it would be comparable with farm-yard manure, excepting that the hyacinth residue is much richer in potash.

It is also worth remembering that if the fresh green plant be immediately stacked for rotting, a very serious loss of valuable material takes place in the liquid exuded during the rotting process. To prevent this, either the whole of the plant should be dried for a few days before stacking, or the fresh plant may be stacked in alternate layers with dried plant: a similar result would be obtained by mixing the fresh plant with earth or with dried weeds or jungle.

The well-dried plant is only about one-twentieth of the original green weight. It is therefore in a much more convenient state for transport than either the fresh plant or the rotted material. Its weight, per unit of mineral plant food, is about five times that of the ash, of which it contains from 20—25 per cent., including about 8 per cent. of potash (K_2O).

Its bulk is considerable; but on the other hand it contains organic matter and from 1·5 per cent. to 2 per cent. of nitrogen, both of which are lost on burning.

The ash of the hyacinth is of course the most convenient form to reduce the plant to if transport is the object. It only forms about 1 per cent. by weight of the original green plant, whereas the dried plant is five times heavier; but in reducing its bulk by burning the dried plant all the nitrogen and organic matter are lost. Nevertheless the whole of the mineral constituents are recovered in an easily available form.

Messrs. Shaw, Wallace & Co. of Calcutta have offered to buy hyacinth ash on the terms described in the following letter :—

4, BANKSHALL STREET, CALCUTTA.
The 12th August, 1916.

To

The Fibre Expert to the Government of Bengal,
C/o The Director of Agriculture,
Writers' Buildings, Calcutta.

SIR,

With reference to the interview of our Mr. Arnold with the Acting Director of Agriculture, Mr. McLean, and yourself on the subject of the ash of the water hyacinth, we are prepared to consider the purchase of the whole of the ash produced from the water hyacinth in India and Burma. We understand that in the first instance, the details of collection of the weed will be carried on by a local contractor, or contractors, when you find suitable responsible men.

The present price which we can offer you is Rs. 4 per full unit of potash f.o.r. or f.o.b. Calcutta. If the ash reached us in good condition and is not adulterated we estimate that it will work out at a minimum price of Rs. 84 per ton. Based on your analysis, it would be Rs. 112. Our procedure would be to make one analysis of each delivery of 5 tons of ash, and pay on the basis of that analysis.

We should esteem it very much if you will make it known among the agriculturists and those who can promote the scheme and we hope to hear from you how the matter is received by them, and later on what progress is being made. To make the collection of potash in this way successful, we would point out that the present time is most favourable, as other sources of potash are temporarily restricted.

Should the matter be taken up seriously, we would like to know what shipments we may expect and the date on which they will begin.

We have the honour to be,
SIR,
Your most obedient servants,
SHAW, WALLACE & CO.

Summary.

(1) The analytical figures detailed above indicate that, in Bengal, water hyacinth (*Eichornia crassipes*) contains considerable stores of valuable plant food of which potash is the chief constituent. If rotted the residue contains about the same amounts of nitrogen and phosphoric acid as, perhaps rather more than, ordinary farmyard manure ; and it is several times as rich in potash.

(2) The fresh green plant contains about 95 per cent. of water and could not be economically transported over any great distance. The rotted plant, containing about 60 per cent. of water, is comparable with cowdung in this respect, and it is likely therefore that the use of the

rotted material will be confined to the immediate neighbourhood of its production.

(3) The dried material is only about one-twentieth of the weight of the green plant: and is thus in a much more convenient form for transport than either the green plant or the rotted material. It contains from 1·5—2 per cent. of nitrogen and about 8 per cent. of potash (K_2O).

(4) After burning, the ash residue of clean water hyacinth (unmixed with earth) has been found to contain as much as 35 per cent. of potash (K_2O) and an average figure for the Dacca District would seem to be over 25 per cent. The ash is therefore several times richer in potash than ordinary wood ashes.

(5) Messrs. Shaw, Wallace & Co. of Calcutta have offered to purchase any quantity of hyacinth ash on the terms detailed in their letter quoted above, *viz.*, Rs. 4 per unit of potash landed in Calcutta. This corresponds to from about Rs. 84 to Rs. 120 per ton.

(6) The results of the field tests, detailed herein, shew conclusively that water hyacinth is a valuable manure, either in the rotted state, or as ash, on laterite soils of the old alluvium in Bengal. Some of the various types of silt which compose the new alluvial tracts also exhibit, in a modified degree, the deficiency in potash, phosphoric acid and lime which is characteristic of the red soils of North-Eastern India, and there is little doubt that hyacinth either rotted or as ash, will prove an equally valuable manure for them. A good deal of evidence to this effect is already available. On the high, light, well-drained soils the rotted material might be preferable; but on heavy low-lying lands the ash would probably be more successful.

(7) Two hundred Presidents of Panchayets in the Dacca District were brought to the Dacca Farm in August 1916 by Mr. Hart, Collector of Dacca, and were shewn the jute crop on the experimental plots which had been manured with hyacinth.

(8) In consultation with Mr. Hart, leaflets in English and Bengali have been drawn up containing information regarding the uses to which the water hyacinth can be put: 10,000 leaflets in Bengali and 1,000 in English have recently been distributed in the Dacca District by Mr. Hart.

(9) There are already indications that the cultivator is beginning to appreciate the agricultural possibilities of water hyacinth. As the knowledge spreads in a densely populated tract like Eastern Bengal, where moreover one of the staple crops like jute answers to heavy manuring there is a powerful incentive for the people to solve the problem for themselves, either individually or collectively, through village or co-operative agencies.

Much credit is due to Mr. N. C. Basu, M.Sc., and to Babu Tara Nath Ray, Chemical Assistant and Field Assistant, respectively, on the staff of the Fibre Expert, for careful work in connection with this investigation.

DACCA,
January 6, 1917.

The interval since the above note was written has afforded an opportunity of judging how far the suggestions put forward for the control of water hyacinth in Bengal are likely to be effective. In the first place a definite start has been made by the public in the conversion of the plant into ash, and the fact that about 170 tons (roughly 4,500 maunds) of ash have actually been sold in Calcutta and Dacca speaks for itself. These figures which take no account of ash which may have been made, and applied to land in the district where it was produced, represent the destruction of about 17,000 tons (four and a half lakhs of maunds) of the green plant.

It is hardly necessary to point out that the above quantities are only a very small fraction of the enormous total which has to be dealt with; but it is also equally obvious that an encouraging start has now been made.

Further investigation has shown that the composition of the ash varies considerably with the conditions under which the plant grows. In the water courses in Dacca City the growth of the plant is very luxuriant, reaching as great an above-water-height as 3 feet. Such big plant has been found to contain the richest ash. On the other hand, the plant growing on land, or in shallow water, especially in the red soil districts, is usually stunted. It often contains a large percentage of ash, but the greater portion of this proves to be silica and the potash content is comparatively low. Analyses of the ash of tall plant from the Dacca *khal* and from a tank at Mirpur on the red soil are appended :—

		Plant from Dacca *khal*		Plant from Mirpur (red soil)	
Ash in dried plant		30·6	per cent.	29·8	per cent.
containing	SiO_2. . . .	20·72	,,	49·43	,,
	K_2O. . . .	34·15	,,	11·36	,,
	P_2O_5	8·20	,,	1·41	,,
	CaO	8·43	,,	7·79	,,
	Cl	20·37	,,	5·66	,,

The ash of No. I would be worth Rs. 5 per maund (80 lb.) f. o. r. Calcutta, on the basis Rs. 4 per unit of potash. Moreover, its content of phosphoric acid adds roughly R. 1 per maund (80 lb.) to its value, making a total approximating to Rs. 6 per maund.

No. II has only one-third the potash content of No. I and is the poorest sample of clean plant ash yet examined. It is worth about Rs. 1-11-0 per maund.

It has been found that a considerable proportion of the potash in the dead hyacinth plant can be extracted with cold water. Therefore the preparation, either of ash or of rotted material, is to be avoided in Bengal during the rainy season. From the middle of October till the end of March would appear to be the most suitable time for these operations.

12th June, 1917.

R. S. F.
K. M.

CALCUTTA : PRINTED BY SUPDT. GOVT. PRINTING, INDIA, 8, HASTINGS STREET.